Chapter 6

Hudson-Raritan Estuary Case Study

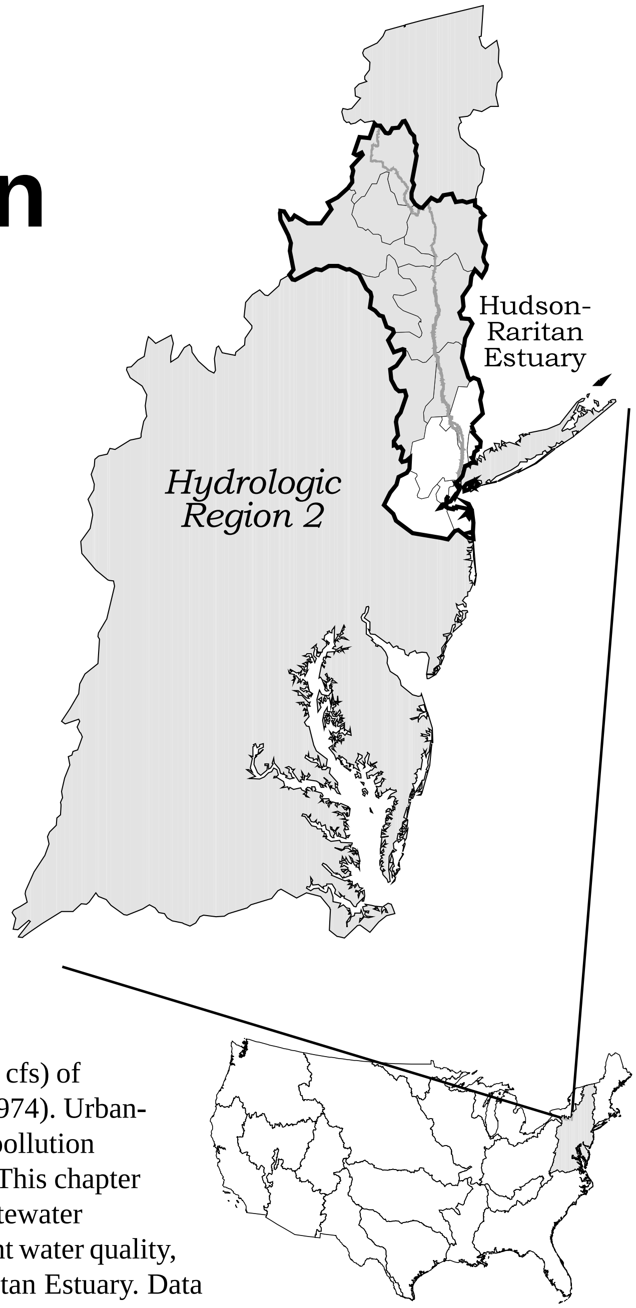


Figure 6-1

Hydrologic Region 2 and Hudson-Raritan estuary watershed.

The Mid-Atlantic Basin (Hydrologic Region 2), covering a drainage area of 111,417 square miles, includes some of the major rivers in the continental United States. Figure 6-1 highlights the location of the basin and the Hudson-Raritan Estuary, the case study watershed profiled in this chapter.

With a length of 306 miles and a drainage area of 13,370 square miles, the Hudson River ranks 71st among the 135 U.S. rivers that are more than 100 miles in length. On the basis of mean annual discharge (1941-1970), the Hudson ranks 26th (19,500 cfs) of large rivers in the United States (Iseri and Langbein, 1974). Urban-industrial areas in the watershed caused severe water pollution problems during the 1950s and 1960s (see Table 4-2). This chapter presents long-term trends in population, municipal wastewater infrastructure and effluent loading of pollutants, ambient water quality, environmental resources, and uses of the Hudson-Raritan Estuary. Data sources include USEPA's national water quality database (STORET), published technical literature, and unpublished technical reports ("grey" literature) obtained from local agency sources.

Background

The Hudson-Raritan Estuary, with its rich and diverse populations of birds, fish, and shellfish, is unmatched in terms of the historical abundance of its natural resources. New York City, in fact, owes its existence as a major urban center to the bounty of the estuary (Trust for Public Lands, 1990). The estuarine and coastal waters around New York City support significant fish and wildlife resources (Sullivan, 1991). For example, the extensive wetland systems along the Arthur Kill on northwest Staten Island, adjacent to one of the most industrialized corridors in the northeastern United States, has recently been colonized by several species of herons, egrets, and ibises (Trust for Public Lands, 1990). Current heron populations represent up to 25 percent of all nesting wading birds along the coast from Cape May, New Jersey, to the Rhode Island line (HEP, 1996). Today, despite mounting pressures for industrial and residential development, there is a growing awareness of the estuary's unique ecological function and a new appreciation of its almost limitless potential as a recreational, cultural, and aesthetic resource (Trust for Public Lands, 1990).

For more than 300 years, New York Harbor and the New York metropolitan region have been a focal point of urban development, transportation, manufacturing, and commerce. New York City has been characterized by tremendous population increases and economic growth and has traditionally been a major Harbor. As a large estuary with vast wetlands and marsh areas, New York harbor offered an abundance of natural resources that supported a commercially important shellfish industry until its decline in the early 1900s. With a relatively deep protected estuary that was ideal for navigation, the harbor developed as a key shipping and transportation link for commerce and passenger traffic between the inland states and Europe.

Physical Setting and Hydrology

New York Harbor is formed by a network of interconnected tidal waterways along the shores of New York and northern New Jersey; it is bounded by the Hudson River to the north, Long Island Sound to the east, and the Atlantic Ocean to the south (Figure 6-2). Freshwater tributaries discharging into the estuary drain an area of 16,290 square miles and contribute approximately 81 percent of the total freshwater inflow to the harbor. The remainder of the freshwater input is contributed by wastewater (15 percent); urban runoff (4 percent); CSOs (1 percent); and industrial discharges, landfill leachate, and precipitation (0.5 percent) (Brosnan and O'Shea, 1996a). Fresh water is also imported into the New York City water supply system from the combined watershed areas of the Delaware and Catskills mountains with eventual discharge via the wastewater drainage system into the harbor.

Seasonal and interannual variation of streamflow of the Hudson River recorded at Green Island, New York, near Troy (USGS gage 01358000) is characterized by high flow during March through May, with the monthly mean peak flow of 32,719 cfs observed in April (Figures 6-3 and 6-4). High spring flows result from spring snowmelt and runoff over the mountainous drainage basin. Low-flow conditions occur during July through September, with the mean monthly minimum of 5,797 cfs observed during August. In dramatic contrast to the long-term (1951-80) summer (July-September) mean of 6,396 cfs, during the extreme drought conditions of 1962-1966, mean summer flow was only 49 to 70 percent of the long-term mean summer flow. The driest conditions occurred during the summer of 1964 with a mean flow of 3,104 cfs and a minimum flow of only 1,010 cfs (Bowman and Wunderlich, 1977; O'Connor et al., 1977). Inspec-

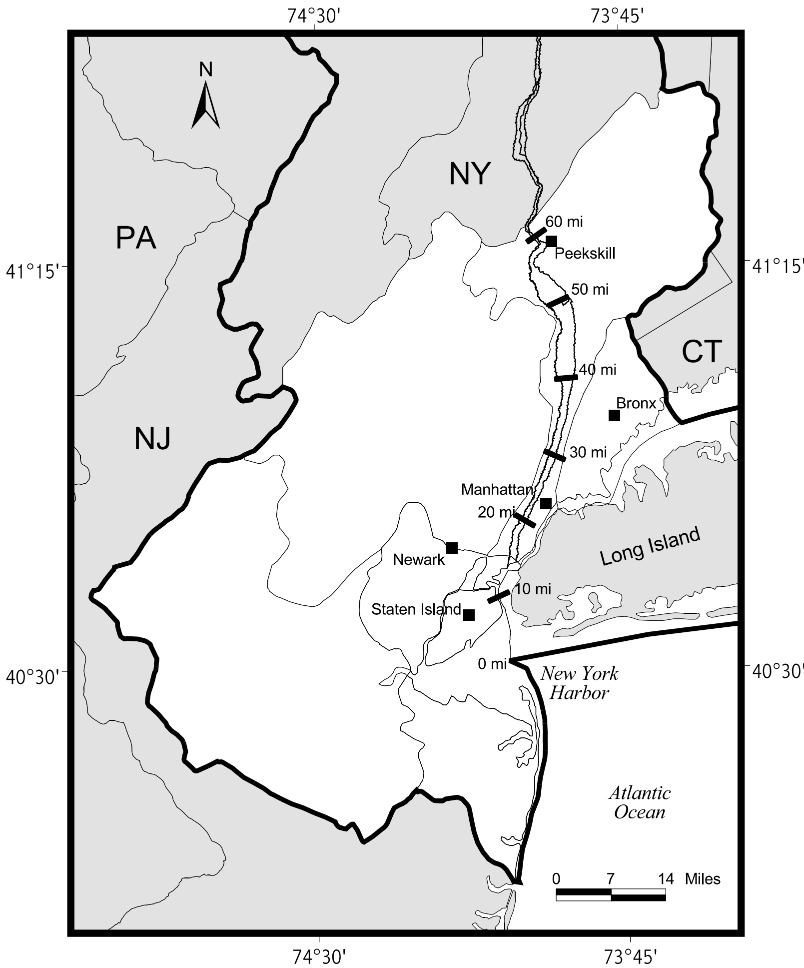


Figure 6-2

Location map of the Hudson-Raritan Estuary. (River miles shown are distances from Sandy Hook-Rockaway transect of Atlantic Ocean.)

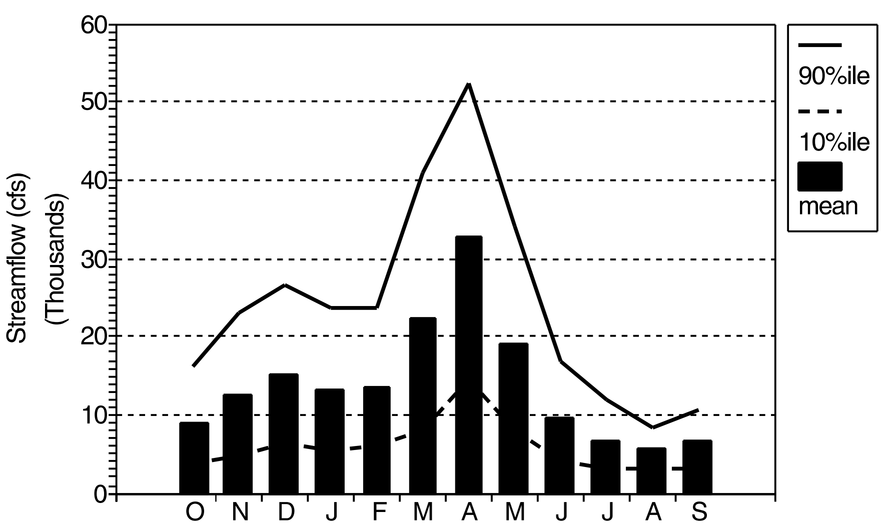


Figure 6-3

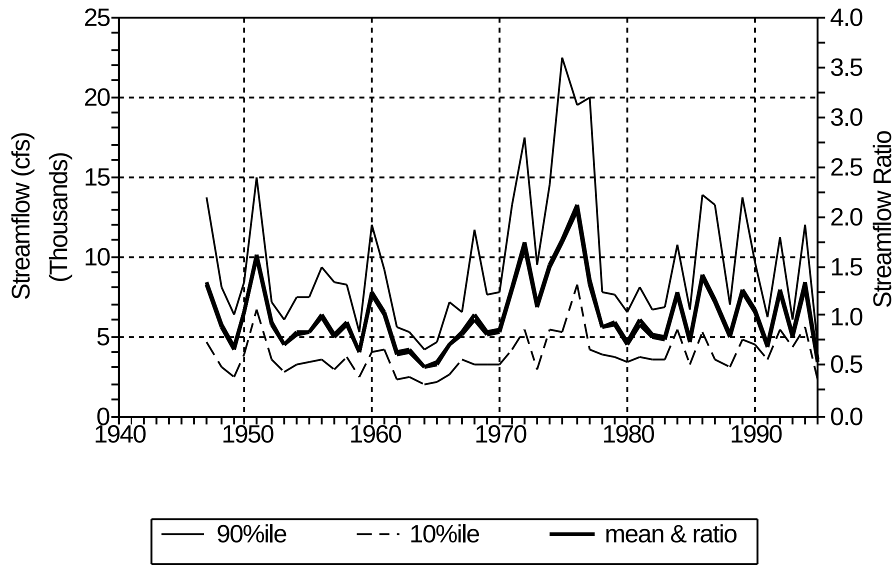
Monthly trends of mean, 10th, and 90th percentile streamflow for the Hudson River at Green Island, NY (USGS Gage 01358000), 1951-1980.

Source: USGS, 1999.

Figure 6-4

Long-term trends in mean, 10th, and 90th percentile streamflow in summer (July-September) for the Hudson River at Green Island, NY (USGS Gage 01358000).

Source: USGS, 1999.



tion of the long-term trend data (1947-1995) for summer streamflow clearly shows the persistent drought conditions of the 1960s, as well as the high-flow conditions recorded a decade later (Figure 6-4).

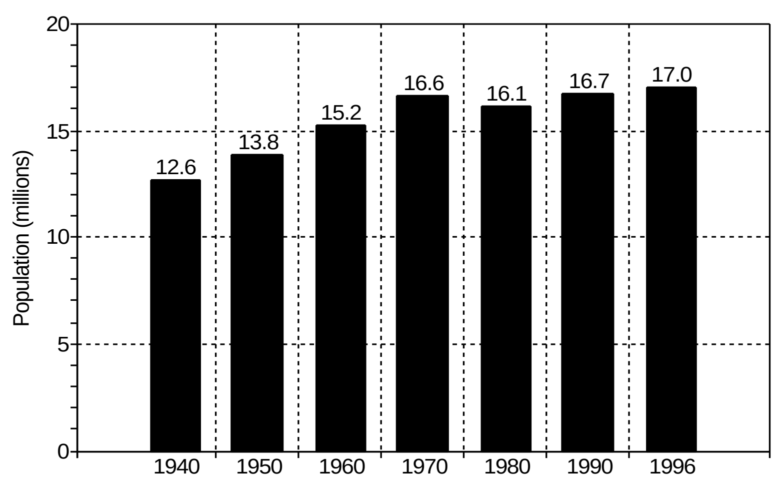
Population, Water, and Land Use Trends

In 1628 New York City was a small village of 270 settlers; today it is an urban metropolis of 16 million (Figure 6-5). The physical environment of the New York region has contributed greatly to its enormous growth and economic development. The natural port of the harbor has made commerce and shipping a major component of the economy since the colonial era. The Watchung and Ramapo mountains, west and northwest of the city, also focused growth around the harbor by constraining transportation routes and land development patterns. In 1810 New York emerged as the largest city in the new nation, surpassing Boston and

Figure 6-5

Long-term trends in population for the New York-Northern New Jersey-Long Island CMSA counties for the Hudson-Raritan Estuary metropolitan region.

Source: Forstall, 1995; USDOC, 1998.



Philadelphia. New transportation routes—the Erie Canal in 1825 and railroad connections between New York and Philadelphia in 1839—strengthened the city's link to Europe and the Nation's interior. During the massive European immigration period of the mid-1800s to the early 1900s, immigrants to the United States passed through Ellis Island in New York Harbor, a main port of entry. Many chose to remain and contribute to the growth of the city.

The Hudson-Raritan Estuary case study area includes a number of counties identified by the Office of Management and Budget (OMB) as Metropolitan Statistical Areas (MSAs) or Primary Metropolitan Statistical Areas (PMSAs). Table 6-1 lists the MSA and counties included in this case study. Figure 6-5 presents long-term population trends (1940-1996) for the counties listed in Table 6-1. From 1940 to 1996, the population in the Hudson-Raritan Estuary case study area increased by 34 percent from 12.6 million in 1940 to 17.0 million in 1996 (Forstall, 1995; USDOC, 1998).

Because of the proximity to shipping and other transportation routes, manufacturing and industrial development evolved as a major component of the region's industrial economy and a major contributor to the environmental decline of the area's once bountiful wetlands. New Jersey, the most densely populated state in the Nation, is second only to California in industrialization, and most of the industrial activity of New Jersey is centered around New York Harbor. Within New York City, economic growth has depended on manufacturing, services, world trade, and the city's position as a national and international center for banks, finance, culture, and the arts. Since the turn of the century, and particularly since the development of the automobile and highways, progressive suburban development radiating from the city has transformed the once agricultural region into a densely populated metropolitan area. At a distance of about 60 miles from New York City, however, farmland, rural lands, and low-density suburban towns still characterize the outer fringes of the metropolitan region.

Table 6-1. Metropolitan Statistical Area (MSA) counties in the Hudson-Raritan Estuary case study. *Source: OMB, 1999.*

Fairfield County, CT	Union County, NJ
Litchfield County, CT	Warren County, NJ
New Haven County, CT	Bronx County, NY
Bergen County, NJ	Dutchess County, NY
Essex County, NJ	Kings County, NY
Hudson County, NJ	New York County, NY
Hunterdon County, NJ	Orange County, NY
Middlesex County, NJ	Putnam County, NY
Monmouth County, NJ	Queens County, NY
Morris County, NJ	Richmond County, NY
Ocean County, NJ	Rockland County, NY
Passaic County, NJ	Westchester County, NY
Somerset County, NJ	Pike County, PA
Sussex County, NJ	

Despite intense development and the loss of wildlife habitat due to wetland conversion, the New York/New Jersey Harbor and the New York Bight do contain significant fish and wildlife resources. Water uses of the Hudson River and New York Harbor include public water supply of the freshwater river upstream of Poughkeepsie, New York, municipal and industrial wastewater disposal, commercial shipping and navigation, recreational boating, swimming, and commercial and recreational fishing. Although commercial fishing was once a significant component of the New York-New Jersey regional economy, the abundance of commercially important fish and shellfish has declined considerably during the past century. The loss of once abundant fishery resources has been attributed to disease, overfishing, loss of habitat, and poor water quality conditions. Despite the significant reductions in fishery resources, commercial fishing of more than 60 species of seafood contributed approximately $500 million to the regional economies of New York and New Jersey during the mid-1990s (Schwartz and Porter, 1994). Recreational fishing in the New York Harbor, Long Island Sound, and New York Bight is also quite important, accounting for more than $1 billion annually in economic activity for New York and New Jersey during the mid-1990s (Schwartz and Porter, 1994).

Historical Water Quality Issues

Waste disposal issues in New York did not emerge only recently. Contemporary residents of the New York metropolitan area would be surprised to learn that public policy debates related to waste disposal and water pollution issues began only a few decades after colonial settlers arrived in the New World. The early settlers' practice of simply dumping pails of sewage and other refuse into the harbor became such a problem that in 1680 the Governor ordered that a common sewer be constructed in Lower Manhattan. In 1683 the Common Council decreed "*that none doe cast any dung, drought, dyrte or any other thing to fill up or annoy the mould or Dock or the neighborhood near the same, under the penalty of twenty shill*" (Gross, 1976). Construction of a sewer and wastewater collection system in New York City began in 1696, with many sewers in lower and central Manhattan constructed two centuries later between 1830 and 1870 (O'Conner, 1990). Pollution problems existed, however, in both New York City and Newark, New Jersey, because the harbor received untreated wastewater from the sewers.

In 1868 unsanitary conditions were described as "*poisoning the water and contaminating the air*" (Suszkowski, 1990). During the 1920s the overpowering stench of hydrogen sulfide from polluted water in the Passaic River near Newark, New Jersey, forced excursion boat passengers to seek refuge in the cabins (Cleary, 1978). During that period, all the regional New York and New Jersey communities discharged raw sewage into the harbor "*to conduct by the cheapest route to the nearest waterway, giving no thought whatever to its effect on the waterway and on adjacent waters*" (Franz, 1982). In the 1920s New York City discharged approximately 600 mgd of raw sewage into the harbor (Brosnan and O'Shea, 1996a).

The earliest water pollution surveys of New York Harbor began with the formation of the Metropolitan Sewerage Commission of New York in 1906. In a 1910 report on conditions of the harbor, the Commission stated that "*Bathing in*

New York Harbor above the Narrows is dangerous to health, and the oyster industry must soon be entirely given up." The Commission further noted that a number of tributaries and tidal channels in the harbor "*have become little else than open sewers. Innumerable local nuisances exist along the waterfront of New York and New Jersey where the sewage of the cities located about the harbor is discharged* . . . ." Finally, the commission concluded that "*the water which flows in the main channels of the harbor . . . is more polluted than considerations of public health and welfare should allow*" (Suszkowski, 1990). As with many other urban areas around the turn of the century, development of a combined drainage network for storm water and sewage collection evolved to address public health problems resulting from inadequate methods of waste disposal that created a nuisance in the streets and contaminated ground water supplies (Fuhrman, 1984).

With vast marshlands, embayments, and interconnecting tidal channels, New York Harbor once supported abundant populations of fish, shorebirds, and shellfish that were important local food resources and essential to certain commercial activities. The progressive decline of the once thriving oyster industry provides an important ecological indicator of the trends in environmental quality of New York Harbor. Commercially important oyster beds were harvested during the 1800s in Raritan Bay, the Kill Van Kull, Jamaica Bay, and Newark Bay, and in the Shrewsbury River. By the turn of the century, waste disposal from industries and towns began to seriously affect the survival of seed beds. In addition to industrial waste and sewage discharges, dredging and disposal of dredge spoils, illegal dumping of cellar dirt, street sweepings, and refuse all contributed to the demise of this once valuable estuarine resource.

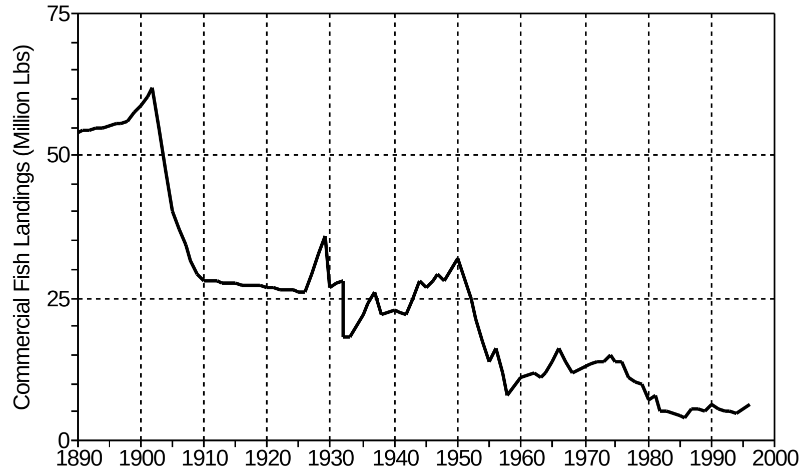
Although a century of pollution, disruption of habitat, and mismanagement of seed beds all contributed to the decline of oyster abundance, bacterial contamination from raw sewage disposal was the catalyst for the death of the commercial oyster industry. As early as 1904, typhoid cases were linked to consumption of contaminated oysters. By 1915, 80 percent of the city's 150 typhoid cases were attributed to contaminated oysters harvested from the harbor. In 1924 and 1925 another major outbreak occurred, even though many of the beds had been closed in 1921 because of public health reasons (Franz, 1982). More than three decades later, consumption of sewage-contaminated hard clams from Raritan Bay again resulted in serious public health problems with an outbreak of infectious hepatitis in 1961.

Oysters, however, were not the only natural resource to suffer serious depletion of once-abundant stocks. In the closing decades of the 19th century, pollution and habitat destruction had begun to seriously degrade water quality and affect the abundance of marine resources. A century-long record of commercial fishery landings for New York and New Jersey clearly documents the adverse impact of water pollution and habitat destruction on the rich natural resources of the estuary (Esser, 1982). Combined landings of important estuarine and anadromous species such as shad, alewife, striped bass, sturgeon, American oyster, hard clam, and bay scallop have declined 90 percent over the past century from 58 million pounds in 1887 to 6.6 million pounds in 1996 (McHugh et al., 1990; Wiseman, 1997) (Figure 6-6). In interpreting this long-term trend, it is important to realize that even a century ago resource abundance was already considered depleted in comparison to reports of abundance recorded through 1850. Contem-

Figure 6-6

Long-term trend of commercial landings of major anadromous and estuarine species in New York Harbor.

Source: McHugh et al., 1990; Wiseman, 1997.



porary degradation of the resources of the estuary, marked by successive anthropogenic assaults and incremental improvements in wastewater treatment, is believed to have begun as early as 1870 (Carriker et al., 1982).

The connection between raw sewage disposal and the decline of the oyster beds in the lower Hudson River eventually led to the creation of the New York Bay Pollution Commission in 1903 and the Metropolitan Sewerage Commission in 1906 (Franz, 1982). Routine water pollution surveys have been conducted in New York Harbor since 1909. This unique data set represents the longest historical record of water quality in the Nation and one of the longest historical records in the world (O'Connor, 1990; Bronsand and O'Shea, 1996a). Historically, water quality problems in the harbor have included severe oxygen depletion and closure of shellfish beds and recreational beaches due to bacterial contamination. More recently, nutrient enrichment, algal blooms, heavy metals, sediment contamination, and bioaccumulation of toxics such as PCBs in striped bass (Faber, 1992; Thomann et al., 1991) and bald eagles (Revkin, 1997) have also become areas of concern.

By the 1920s summer oxygen within much of the harbor had deteriorated to critical levels of less than 20 percent saturation (Brosnan and O'Shea, 1996a). Along with oyster industry records, long-term DO records document a progressive decline in the environmental quality of the harbor from 1910 through about 1930 as a result of increased population growth and raw sewage loading to the harbor (Brosnan and O'Shea, 1996a; Wolman, 1971). Following a period of very low oxygen saturation from about 1920 through 1950, the subsequent increasing trend generally corresponds chronologically to incremental improvements in construction and upgrades of sewage treatment plants beginning in 1938 (Brosnan and O'Shea, 1996a).

With the completion of New York City's last two sewage treatment plants in 1986-1987, one of the major remaining water pollution problems in the harbor results from combined sewer overflows that discharge raw sewage and street debris. Following storm overflows, high bacteria levels require the closing of shellfish beds and bathing beaches. Although an aggressive industrial pretreatment program reduced the total industrial metal contribution to New York City plants from 3,000 lb/day in 1974 to 227 lb/day in 1991 (Brosnan et al., 1994), early ambient data still suggested violations of state water quality standards for metals in many locations of the harbor. More recent investigations conducted under the auspices of the NY/NJ Harbor Estuary Program (HEP) indicated significantly lower metal concentrations, with harborwide exceedances found only for mercury. Current monitoring and modeling efforts have greatly reduced the extent of waters suspected to be in violation of standards for nickel, lead, and copper (Stubin, 1997).

Additional toxic chemical problems in the harbor are associated with PCB contamination of sediments and striped bass and other marine organisms resulting from the discharge from two General Electric plants upstream of Albany from the 1940s through the mid-1970s (Thomann et al., 1991). With a commercial fishing ban imposed because of PCB contamination (Faber, 1992), the striped bass population is thriving to the extent that the abundance of contaminated bass caught in nets and then returned to the estuary is actually creating an economic hardship for the commercial shad fishery (Suszkowski, 1990). More recent state-of-the-art monitoring and analysis technologies have detected trace level concentrations of PCBs in regional sewage treatment plant effluents. Current track-down programs, again initiated under the auspices of HEP, seek to determine the sources of these PCB contributions to the municipal waste stream.

Legislative and Regulatory History

Responding to the increasingly polluted conditions of the estuary, in 1906 the New York State legislature directed the city of New York to form the Metropolitan Sewerage Commission of New York. This commission was charged with the dual tasks of investigating the extent of water pollution in the harbor and formulating a plan to improve city sanitary conditions. In addition to recommendations for upgrades of waste treatment, which eventually were implemented beginning in the 1930s, the Commission also recommended that outfalls be relocated from nearshore to a central diffuser in the Lower Bay. A central diffuser system, however, was never adopted (Suszkowski, 1990).

Construction of primary wastewater treatment plants in the Hudson-Raritan estuary began with Passaic Valley, New Jersey, coming on line in 1924 followed by Yonkers, New York, in 1933. During the construction of the first treatment plants in the 1930s and 1940s in New York City, the New York City Department of Public Works maintained an active role in research and development of waste treatment processes, particularly in the area of biological waste treatment. Although the federal government’s primary role was to provide technical advice through the Public Health Service, the Roosevelt Administration did provide federal public works funding for sewage treatment plant construction as a relief program during the Great Depression (O’Connor, 1990). Because of the regional nature of water pollution problems, New York, New Jersey, and Connecticut established the Interstate Sanitation Commission (ISC) to develop water quality standards and to report on progress in water pollution control in the harbor.

Following the passage of the Federal Water Pollution Control Act and amendments in 1948 and 1956, the federal government began to assume a larger role in funding for water pollution control. Beginning in 1956 and continuing on a much larger scale with the 1972 CWA, the Construction Grants Program has provided funding for construction of municipal wastewater treatment plants (see

Chapter 2). Following the 1965 Federal Water Pollution Control Act, federal funding through the Public Health Service and the Federal Water Pollution Control Administration was also available to provide technical assistance in monitoring and analysis to investigate water quality management issues (FWPCA, 1965, 1969). Under the 1972 CWA, areawide 208 studies were conducted to evaluate regional water quality management solutions related to waste treatment facility needs (Hazen and Sawyer, 1978; O'Connor and Mueller, 1984). Authorization for New York City Department of Environmental Protection (NYCDEP) to oversee its own industrial pretreatment program for corrosion control in 1987 has led to significant reductions in heavy metal loadings (Brosnan et al., 1994). A citywide CSO Abatement Program is under way to comply with USEPA's national CSO strategy. New York City has allocated $1.5 billion for construction of CSO abatement facilities over the next 10 years and is proceeding with water quality studies and facility planning. In the meantime, the city implemented the "Nine Minimum Controls" issued by USEPA as part of the 1994 National CSO Control Policy, with significant improvements in water quality conditions (Brosnan and Heckler, 1996; Heckler et al., 1998). Since enactment of the 1965 amendments to the Federal Water Pollution Control Act, $7.5 billion has been invested by federal, state, and local governments to upgrade 11 of 12 water pollution control plants and to construct and upgrade the North River and Red Hook plants (Adamski and Deur, 1996).

With limited open land area, sludge disposal has always been a major problem for the New York-New Jersey region. In 1924 New York City began routine ocean disposal of sewage sludge at a dump site 12 miles south of Rockaway off Long Island. Over the following five decades, New Jersey and Westchester County also used ocean dumping to disposal of sewage sludge. By 1979, 5.4 million metric tons of sewage sludge solids (5 percent) had been dumped into the shallow (30-m) site (Mueller et al., 1982). Because of the ecological effects, and the resulting political and public controversy (NACOA, 1981), ocean dumping at the 12-mile site was abandoned in 1985. Sludge disposal was then moved to a deepwater site 106 miles offshore until this practice was ended in 1992. New York City has subsequently constructed eight sludge dewatering facilities and is relying on private contractors to handle its sewage sludge. Long-range plans for the year 1998 called for direct application of dewatered sludge for beneficial land use (Schwartz and Porter, 1994).

Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends

Beginning with decisions by local authorities to construct an organized sewage collection system in Lower Manhattan as early as 1696, a complex network of stormwater and sewage collection systems and wastewater treatment plants has evolved over the past 300 years, initially to minimize nuisances and protect public health, and most recently to restore and protect the estuarine environment. In 1886 the first wastewater treatment plant was constructed to protect bathing beaches at Coney Island. Following recommendations of a 1910 master plan for sewage treatment by the Sanitary Commission, New York City, Passaic Valley, New Jersey, and Yonkers, New York, initiated construction programs, beginning in the mid-1920s at Passaic Valley, for wastewater plants (O'Connor, 1990).

Following a master plan from the Metropolitan Sewerage Commission, the City of New York began construction of the first modern wastewater treatment facility at Coney Island in 1935 and three plants discharging to the East River in 1938. Other locations also constructed municipal wastewater treatment plants at that time. Modern treatment plants went on-line in 1938 at North and South Yonkers, New York, designed for a combined discharge of 130 mgd into the Hudson River; Passaic Valley, New Jersey, first constructed a plant in 1924 and upgraded it in 1937 to 250-mgd capacity. By 1952 a total of 11 water pollution control facilities were operational in New York City. Upgrades to seven of the existing facilities during the 1950s and 1960s gradually resulted in improvements in water quality within the harbor. By 1967 the largest New York City plant, Newton Creek, came on-line discharging 310 mgd into the East River, with New York City's wastewater treatment facilities accounting for a total effluent discharge of approximately 1,000 mgd.

Driven by the regulatory controls of the 1972 Clean Water Act, public works programs in New York City, New Jersey, Connecticut, and Westchester County during the 1970s and 1980s upgraded municipal treatment facilities to full secondary treatment. In 1986 completion of the North River water pollution control plant ended the discharge of 170 mgd of raw sewage into the Hudson River from Manhattan, with secondary treatment attained in 1991. In 1987 completion of the Red Hook water pollution control plant abated the discharge of 40 mgd of raw sewage into the Lower East River from Brooklyn, with secondary treatment attained in 1988. An additional 0.7 mgd of previously unsewered discharge was captured beginning in 1993 when wastewater from Tottenville, Staten Island, was connected to the 40-mgd Oakwood Beach water pollution control plant. Since the completion of the North River plant in 1986 and Red Hook plant in 1987, all wastewater collected in the total sewered area of about 2,000 square miles (Figure 6-7) in the New York metropolitan region has been treated before discharge into the estuary. Within the New York-New Jersey metropolitan region, municipal sewage treatment plants serve approximately 16 million people and discharge about 2,500 mgd (Brosnan and O'Shea, 1996a).

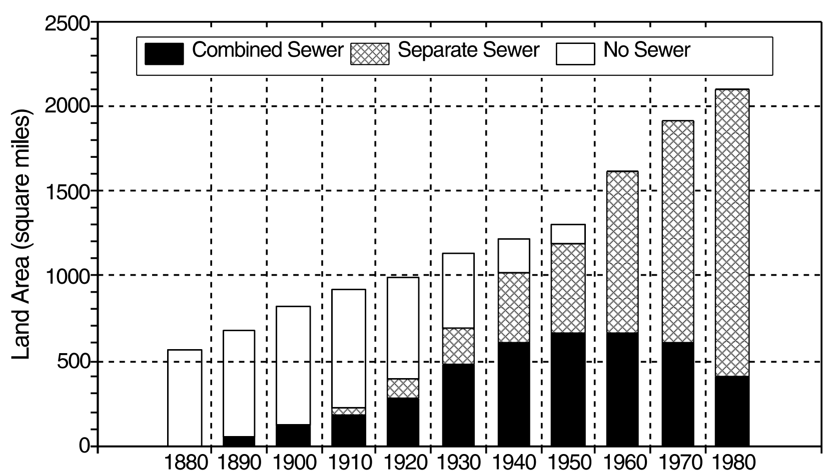


Figure 6-7

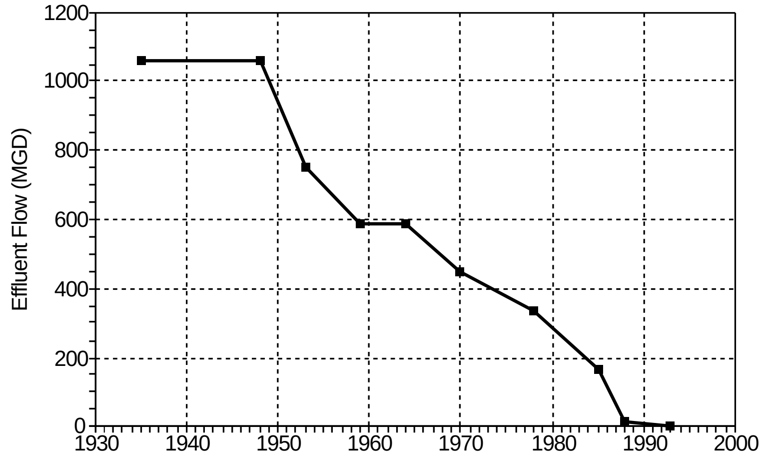
Long-term trend of sewage collection in the Hudson-Raritan Estuary metropolitan region, 1880-1980.

Source: Suskowski, 1990.

Figure 6-8

Long-term trend in untreated sewage discharges to New York Harbor.

Source: Brosnan and O'Shea, 1996b.



From 1979 to 1994, 13 of the 14 municipal water pollution control plants operated by the city of New York were upgraded to full secondary treatment, as defined by the 1972 Clean Water Act (Schwartz and Porter, 1994). The North River (170 mgd) and Red Hook (45 mgd) plants, originally on line in 1986-1987 as advanced primary facilities, were upgraded to full secondary plants in 1991 and 1989, respectively (Brosnan and O'Shea, 1996a). The Newton Creek water pollution control plant is expected to be upgraded to full secondary treatment by 2007 (Schwartz and Porter, 1994). As a result of upgrades to existing plants and construction of the North River and Red Hook plants, the discharge of raw sewage has been reduced from 1,070 mgd in 1936 to less than 1 mgd by 1993 (Figure 6-8). Intermittent raw discharges, caused by malfunctions or construction bypasses, have been reduced from 3.8 mgd in 1989 to 0.85 mgd by 1995 (O'Shea and Brosnan, 1997; Brosnan and O'Shea, 1996b).

The locations of municipal water pollution control plant (WPCP) discharges (> 10 mgd) into the Hudson-Raritan estuary are shown in Figure 6-9. The Hudson-Raritan Estuary receives pollutant loads from a number of different sources in the drainage basin. Table 6-2 illustrates that the relative significance of different sources is dependent on the pollutant considered. Combined sewer

Table 6-2. Pollutant loadings to the Hudson-Raritan Estuary (in percent).[a] *Source: Brosnan and O'Shea, 1996a.*

Parameter	Tributary	Municipal Effluents	Combined Sewer Overflow	Storm Water	Other[b]	Total Load
Flow	81	15	1	4	< 0.5	765 $m^3\ s^{-1}$
Fecal Coliform	2	< 0.1	89	9	< 0.1	$2.1 \times 10^{16}\ d^{-1}$
BOD	16	58	19	5	2	5.7×10^5 kg d^{-1}
TSS	80	11	5	3	1	2.4×10^6 kg d^{-1}
Nitrogen	29	63	2	2	4	2.8×10^5 kg d^{-1}
Phosphorus	16	75	4	4	< 0.5	2.3×10^5 kg d^{-1}

[a] Modified from HydroQual (1991) based on data from the late 1980s. Values across may not equal 100% due to rounding.

[b] Other = industrial discharges, landfill leachate, and direct atmospheric deposition combined.

Figure 6-9

Location of harbor survey sampling sites and municipal water pollution control plants in New York Harbor.

Source: Brosnan and O'Shea, 1996b.

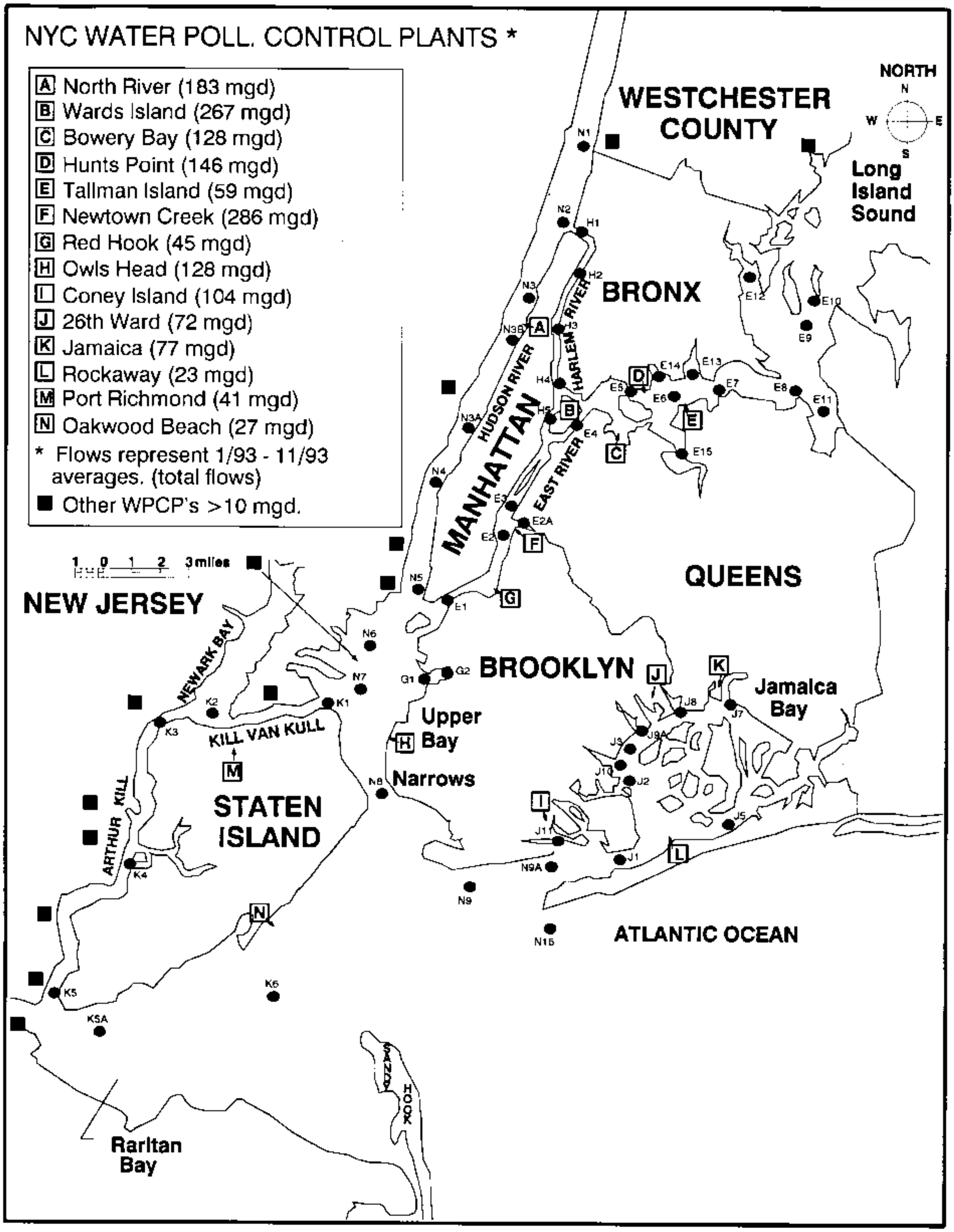


Table 6-3. Distribution of wastewater flows into New York Harbor waterways. *Sources: HydroQual, 1991; O'Shea and Brosnan, 1997.*

Waterway	WPCPs[a] (2,500 mgd)		Direct Industrial Discharges (52 mgd)	
	Flow (mgd)	% Total	Flow (mgd)	% Total
Hudson River	375	15%	3.1	6%
East River	1,050	42%	0.0	0%
Upper New York Bay	375	15%	1.0	2%
Jamaica Bay	300	12%	0.0	0%
Lower New York Bay	125	5%	0.0	0%
Arthur Kill	100	4%	40.0	78%
Kill van Kull	50	2%	0.0	0%
Raritan River	< 25	< 1%	2.1	4%
Hackensack River	100	4%	4.2	8%
Passaic River	0	0%	1.0	2%
Total	*2,500*		*51.4*	

[a] Some municipal dischargers (WPCPs) include industrial dischargers.

overflows, for example, account for only 1 percent of the total freshwater input to the harbor but contribute 89 percent of the total loading of fecal coliform bacteria (Brosnan and O'Shea, 1996a). Effluent from water pollution control plants contributes about one-half to three-quarters of the total load of BOD_5 and nutrients, while watershed runoff via tributaries accounts for 80 percent of the total suspended solids (TSS) load. Table 6-3 presents a summary of the distribution of effluent flows from municipal (WPCPs) and industrial point source discharges to New York Harbor waterways. As presented in Table 6-3, approximately 2,500 mgd of treated wastewater was discharged in 1995 from 81 water pollution control facilities located in New York City, six New Jersey coastal counties, two coastal Connecticut counties, and Westchester and Rockland counties in New York (O'Shea and Brosnan, 1997). Of the total 2,500 mgd, facilities operated by the city of New York accounted for 1,490 mgd in 1995.

With the construction and upgrade of WPCPs, the relative contributions of effluent flow and BOD_5 loading shifted from less-than-secondary to secondary point sources. Figure 6-10 shows the contributions of raw, primary, and secondary facilities to the effluent flow trend of approximately 2,500 mgd from 1970 through 1987. Less than 500 mgd (approximately 20 percent) was accounted for by less-than-secondary dischargers by 1987. With the upgrade of the Coney Island plant to full secondary in 1994, effluent flow from less-than-secondary facilities has been abated completely. Trends in the reduction of effluent BOD_5 loading to the harbor (Figure 6-11) show that total BOD_5 loads from municipal WWTPs have been reduced from approximately 962 metric tons/day in 1970-1974 to 369 metric tons/day by 1987. With the exception of the Newton Creek facility, all municipal facilities in New York City had been upgraded to secondary treatment by 1994-1995. Effluent BOD_5 loading from municipal facilities discharging to the Hudson-Raritan estuary was further reduced to 214 metric tons/day by 1994-1995 (HydroQual, 1999). Most of this substantial reduction is attributed to the elimina-

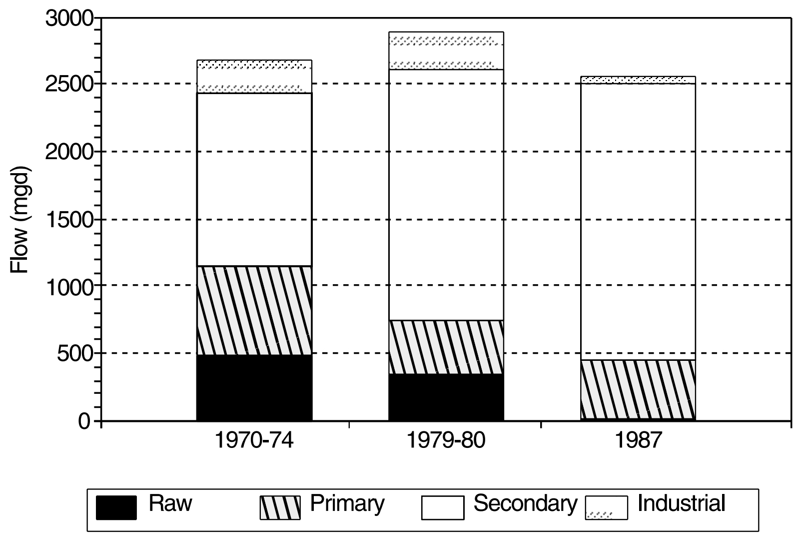


Figure 6-10

Long-term trends in the source contribution of point source effluent flow to New York Harbor.

Source: HydroQual, 1991.

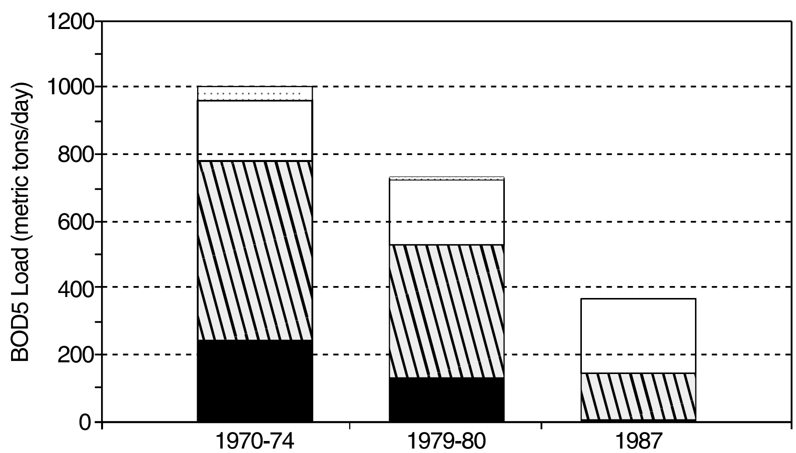


Figure 6-11

Long-term trends in the source contributions of point source effluent BOD_5 loads to New York Harbor.

Source: HydroQual, 1991.

tion of raw sewage discharges on the west side of Manhattan (North River plant) and Brooklyn (Red Hook plant) and upgrades to full secondary treatment. Based on an empirical relationship of BOD_5 loading and observed DO saturation records in the Lower East River (Suszkowski, 1990), historical trends in effluent BOD_5 loading have been estimated for the Lower East River (Figure 6-12). The increase in BOD_5 loading from 1910 to 1930 is attributed to population growth and an expanding sewage collection system (see Figure 6-7), while the reduction in loading from 1930 to 1940 resulted from the construction of three primary treatment plants during the 1930s. After the mid-1960s, the progressive decline in BOD_5 loading was driven by upgrades to full secondary treatment and the elimination of raw sewage discharges from Brooklyn with construction of the Red Hook facility as an advanced primary plant in 1987.

The long-term trend (1880-1980) of historical loading of copper and lead to New York Harbor (Figure 6-13) reflects increasing urbanization and uncontrolled wastewater discharges from industrial activity in the metropolitan region from 1880 through 1970. The reduction in loading of these metals after 1970, resulting from the industrial pretreatment program, corrosion controls, and effluent controls on industrial discharges, corresponds to a decrease in sediment levels of copper and lead in the Hudson estuary (Figure 6-14). Studies conducted at Columbia University have documented a 50 to 90 percent reduction from the 1960s and 1970s in most trace metals and chlorinated organic compounds in fine-grained sediments of the Hudson River (Chillrud, 1996). Sediment toxicity, however, has been identified for the Upper East River, Arthur Kill, Newark Bay, and Sandy Hook Bay. The observed distribution of sediment toxicity appears to be most strongly related to polynuclear aromatic hydrocarbons (PAHs) rather than trace metals (Wolfe et al., 1996). Historical point and nonpoint source loading estimates for the Hudson-Raritan estuary are presented elsewhere for other trace metals, PCBs, total suspended solids (HydroQual, 1991), total organic carbon (Swaney et al., 1996; Howarth et al., 1996) and nutrients (HydroQual, 1991, 1999; Carpenter, 1987). Using a steady-state toxics model, the New York-New Jersey Harbor Estuary Program has also developed mass balance analyses for copper, nickel, and lead and a preliminary mass balance for mercury and PCBs (HydroQual, 1995b).

Long-term water quality records for most locations in the estuary clearly illustrate degradation from population growth and inadequate sewage treatment through the mid-1960s and gradual improvement following construction of waste-

Figure 6-12

Long-term trends of BOD_5 loads to the Lower East River.

Source: Suskowski, 1990.

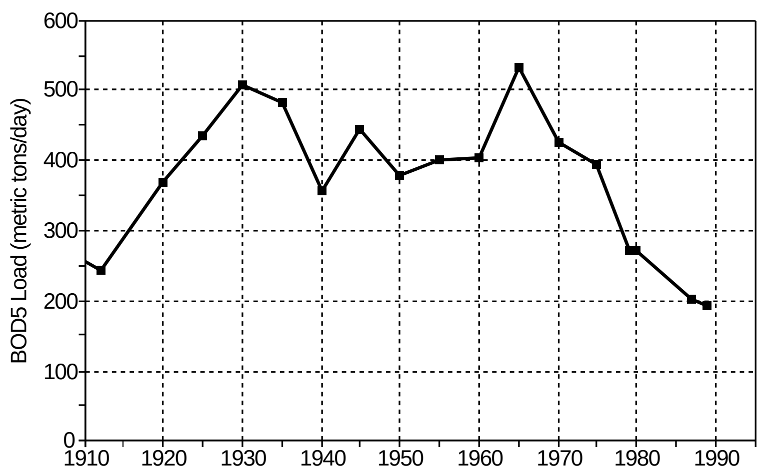
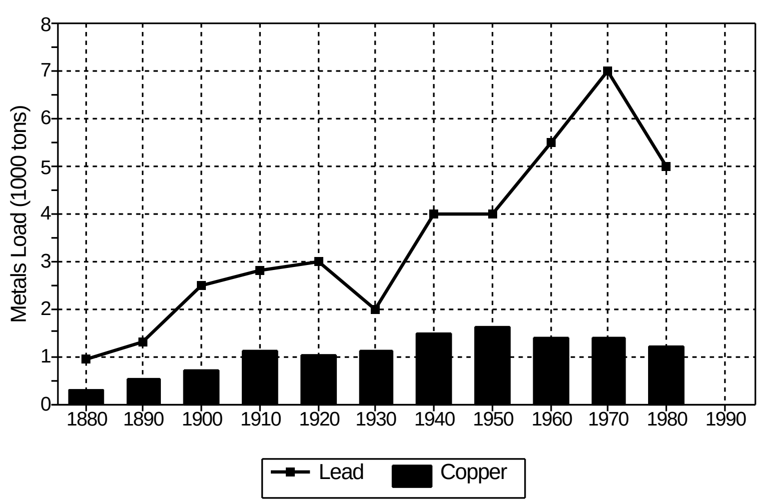


Figure 6-13

Long-term trend of copper and lead loads to New York Harbor.

Source: Suskowski, 1990.



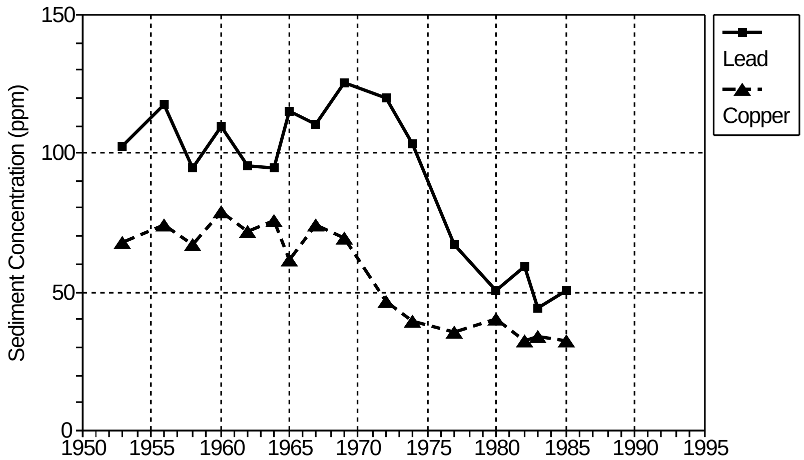


Figure 6-14

Time history of copper and lead in sediment core in the low-salinity reach of the Hudson estuary.

Source: Valette-Silver, 1993.

water treatment plants and implementation of secondary treatment. Using historical data collected at 40 stations in the harbor from 1968 to 1993, an analysis of harborwide long-term trends clearly documents more than an order-of-magnitude improvement in total coliform and fecal coliform concentrations (Figure 6-15). The dramatic decline in bacterial levels is attributed to water pollution control infrastructure improvements that eliminated raw sewage discharges and upgraded all water pollution control plants to include disinfection by chlorination (O'Shea and Brosnan, 1997). Other improvements, reductions of approximately 50 percent in bacterial levels for most areas of the harbor, are attributed to increased surveillance and maintenance of the entire sewage distribution system, including the capture of combined sewage during rain events (Brosnan and O'Shea, 1996b).

Long-term summer DO saturation records, collected almost continuously since 1909 at a station in the Hudson River near 42nd Street on the west side of Manhattan (Figure 6-16) and stations at Baretto Point and 23rd Street in the Upper and Lower East River (Figure 6-17), clearly document the beneficial impact of upgrading water pollution control facilities to full secondary treatment. Over a 40-year period from the 1920s through the 1960s, summer oxygen saturation levels were only about 35 percent to 50 percent at the surface and 25 percent to 40 percent in bottom waters. As a result of significant reductions in biochemical oxygen demand loading (see Figures 6-11 and 6-12), DO saturation levels increased to about 90 percent at the surface and greater than 60 percent in the bottom waters (Brosnan and O'Shea, 1996a). DO concentrations have increased significantly since the 1980s harborwide (Brosnan and O'Shea, 1996a; Parker and O'Reilly, 1991). In many waterways, the greatest oxygen and BOD_5 improvements were recorded between 1968 and 1984, coinciding with the greatest WPCP construction and upgrading activity (O'Shea and Brosnan, 1997). Analysis of data for stations from 1968 to 1995 documents reductions in ammonia-nitrogen (Figure 6-18) and decreases in BOD_5 (Figure 6-19) throughout New York Harbor; exceptions to these decreasing trends include stations in Jamaica Bay and scattered stations in Lower New York Bay and the Upper East River (O'Shea and Brosnan, 1997).

Although not generally appreciated, the poor water quality conditions, particularly low DO levels, that characterized New York Harbor for most of the 20th century actually had a beneficial effect for shipping activities because

Figure 6-15

Long-term trends in summer geometric mean fecal coliform bacteria. Data represent harborwide composite of 40 stations monitored since at least 1970.

Source: O'Shea and Brosnan, 1997.

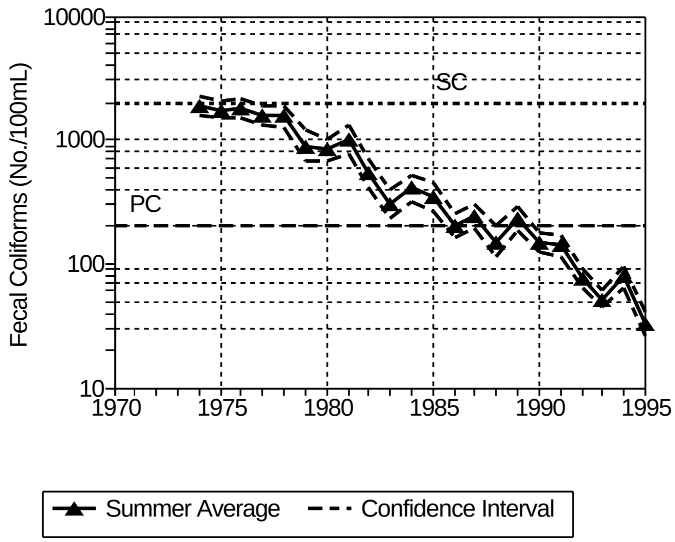


Figure 6-16

Long-term trends of DO (summer average) at 42nd Street in the Hudson River. Triangle markers identify years of upgrades for Yonkers WPCP (1932, 1934, 1956, 1979) and North River WPCP (1986, 1993).

Source: Brosnan and O'Shea, 1996a.

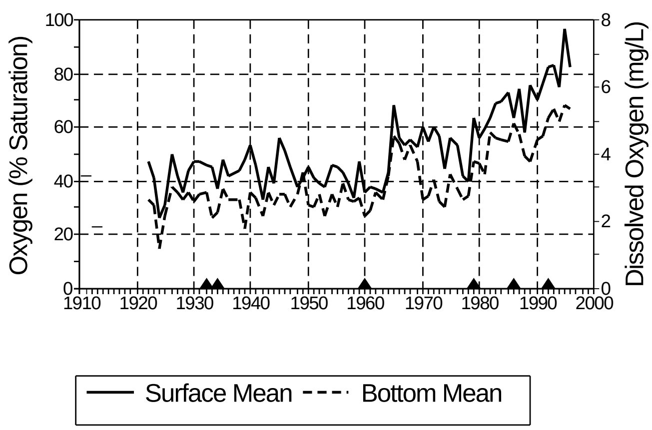
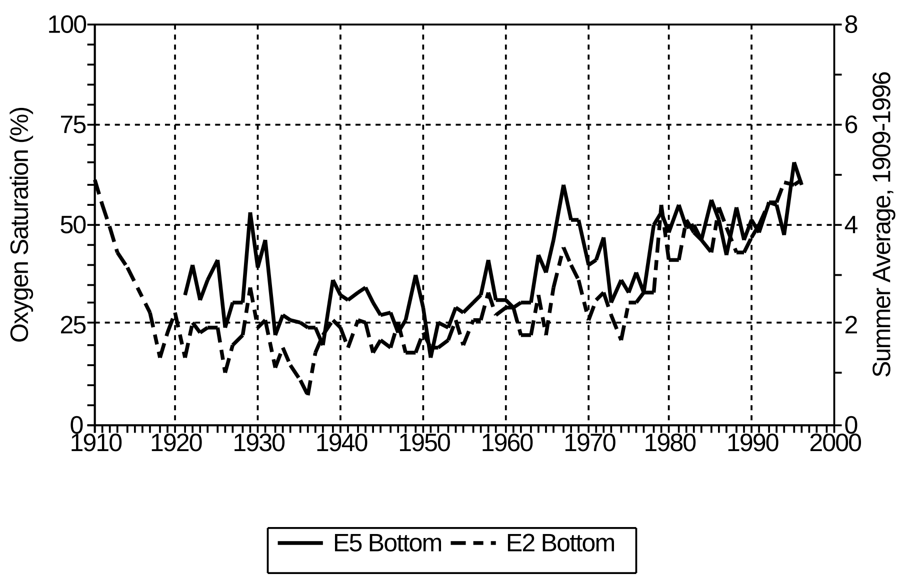


Figure 6-17

Long-term trends of DO (summer average) at Baretto Point (Station E5) in the Upper East River and at 23rd Street (Station E2) in the Lower East River.

Source: Brosnan and O'Shea, 1996a.



wooden pilings and other submerged wooden structures were *not* destroyed by pollution-intolerant marine borers. During the 19th century before water quality had deteriorated in the harbor, abundant populations of shipworms (*teredos*) and gribbles (*limnoria*) quickly devoured driftwood (naturally occurring) and wooden pilings (man-made). This natural ecological activity probably kept the harbor clear of driftwood, but it created severe problems for commercial shipping interests because untreated wooden pilings needed to be replaced after only about 7-10 years (Port Authority of New York, 1988). As water pollution problems increased in the harbor, populations of marine borers declined to such a level that, ironically, wooden pilings and other submerged wooden structures were preserved for many years while submerged in the noxious, oxygen-depleted waters laden with oil, bilge waste, and toxic chemicals. The dramatic improvements in water quality conditions in New York Harbor, as well as other east and west coast harbors, have resulted in a resurgence of thriving populations of marine borers since the mid-1980s (Gruson, 1993) (Figure 6-20). The population boom of marine borers has resulted in severe infestation and rapid deterioration and collapse of wooden

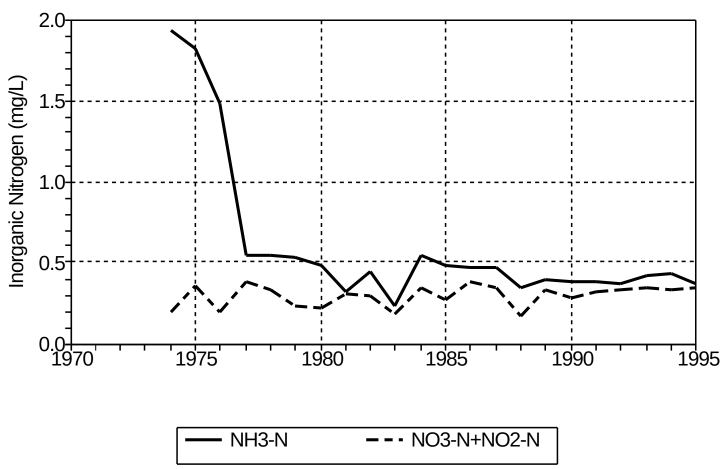


Figure 6-18

Long-term trend in summer mean inorganic nitrogen. Data represent harborwide composite of 40 stations monitored since at least 1970.

Source: O'Shea and Brosnan, 1997.

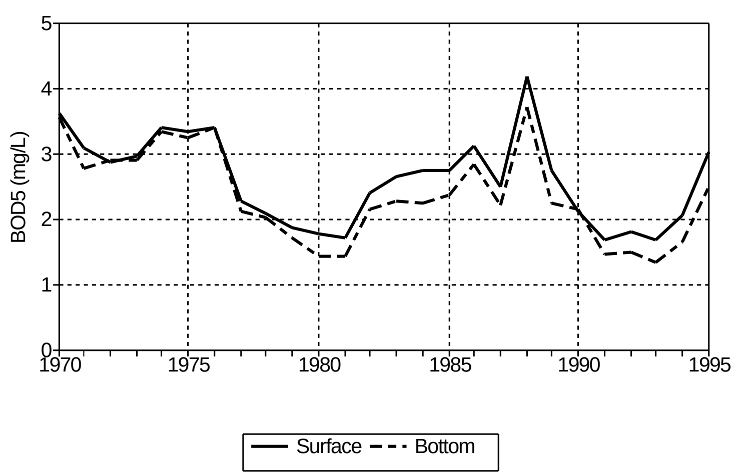


Figure 6-19

Long-term trend in summer mean BOD_5. Data represent harborwide composite of 40 stations monitored since at least 1970.

Source: O'Shea and Brosnan, 1997.

pilings and other submerged wooden structures in New York Harbor from JFK International Airport to New Jersey, including Brooklyn, Staten Island, and the east and west sides of Manhattan (Randolph, 1998; Abood et al., 1995; Metzger and Abood, 1998; Schwartz and Porter, 1994).

Over the past several years, state-of-the-art coupled hydrodynamic and water quality models have been developed for water quality management studies of the harbor, including New York City's Harbor-Wide Eutrophication Model and, most recently, the System-Wide Eutrophication Model (SWEM) (HydroQual, 1995a, 1996, 1999). Earlier models, developed for USEPA's 208 Study of the harbor (Hazen and Sawyer, 1978; Higgins et al., 1978; Leo et al., 1978; O'Connor and Mueller, 1984), have been used to assess the impact of secondary treatment requirements on DO in the harbor. The more recent New York City models, employing improved loading estimates and state-of-the-art hydrodynamics (Blumberg et al., 1997), are being used to determine the feasibility and effectiveness of management alternatives for New York City point sources of nitrogen. For example, SWEM will enable New York City to evaluate options as part of the facility planning for the Newton Creek WPCP, the last remaining plant operated by the city of New York to be upgraded to secondary treatment (HydroQual, 1999). This model is further assisting the New York-New Jersey Harbor Estuary Program in understanding the complex relationships between physical transport processes, nitrogen loading, algal biomass, and DO in New York Harbor, the New York Bight, and Long Island Sound (HEP, 1996).

Impact of Wastewater Treatment: Recreation and Living Resources Trends

Since 1968 the New York City Council has required the New York City Department of Public Health to notify the Department of Parks of beaches that pose a potential health risk to the public. Such beaches were traditionally posted with wet weather advisories, following occurrences of heavy or prolonged

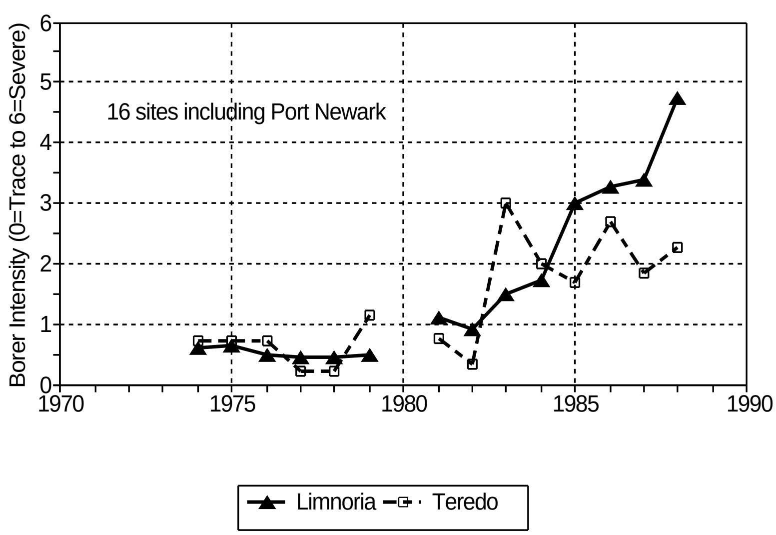


Figure 6-20

Trends in marine borer activity in Upper New York Harbor.

Source: Port Authority of New York, 1988.

rainstorms. These postings have long been replaced with seasonal wet weather advisory postings. The advisories are based on the occurrence of high fecal coliform bacteria concentrations, which may indicate the presence of raw or partially treated sewage and the likely presence of waterborne pathogens. Diseases associated with recreational swimming waters include typhoid fever, gastroenteritis, swimmer’s itch, swimmer’s ear, and some viral infections such as infectious hepatitis (NJDEP, 1990).

The most important source of pollution, contributing about 89 percent of the total fecal coliform bacteria load to the harbor, is wet weather CSOs (Brosnan and O’Shea, 1996a). Large volumes of water generated during rainstorm events, when combined with the regular volume of sewage, overwhelm the capacity of the collection system and discharge the mixture of storm runoff and raw wastewater directly into the harbor. During wet weather events, water quality may be seriously degraded.

Before 1900 untreated wastewater caused severe outbreaks of disease associated with exposure pathways such as shellfish consumption and recreational swimming. Conditions improved somewhat as sewage treatment plants adopted primary treatment as a practice to settle out the solids in wastewater before discharge to the harbor. Pathogen reduction was further enhanced by upgrading water pollution control facilities to secondary treatment with chlorination of the effluent for disinfection. Improvements in municipal wastewater treatment practices have significantly reduced the incidence of waterborne disease outbreaks. Typhoid fever, once a serious swimming-related disease, for example, has not been reported in the last 30 to 40 years (NJDEP, 1990).

During the 1970s and 1980s significant efforts were made to construct and upgrade WPCPs in the Hudson-Raritan Estuary to attain secondary levels of wastewater treatment as mandated by the 1972 Clean Water Act. With upgrades and chlorination of effluent, the discharge of raw wastewater has been reduced from 450 mgd in 1970 to less than 5 mgd by 1988 and essentially zero by 1993 (see Figure 6-8). The most dramatic improvement in bacterial conditions in the harbor occurred in 1986 with the completion of the North River WPCP in Manhattan. Before construction of the primary facility, 170 mgd of raw sewage was discharged into the Hudson River from 50 outfalls on the west side of Manhattan (Brosnan and O’Shea, 1996a). Treatment of the raw sewage and year-round disinfection resulted in a dramatic decline in fecal coliform concentrations. The 1986 data revealed a 78 percent decrease in the fecal coliform concentrations in the Hudson river compared to values measured in 1985 before the primary plant came on-line. When the 45-mgd Red Hook WPCP went on-line in 1987 in Brooklyn, abating the raw sewage discharge from 33 outfalls, fecal coliform concentrations in the East and Lower Hudson Rivers declined by 69 percent within 2 years. Continued improvements in water quality and decreases in fecal coliform bacterial concentrations on the order of 50 percent from 1989 to 1995 are attributed to improved maintenance and surveillance of the sewage treatment system. Management actions that have contributed to these improvements in water quality include abatement of illegal connections, reduced raw sewage bypasses, and increased capture of combined sewage during rain events (Brosnan and O’Shea, 1996b).

“Snapshots” of the distribution of total coliform bacteria from 1972 to 1995 in surface waters of the harbor (Figure 6-21) clearly document the significant reductions in bacterial concentrations that resulted from implementation of controls to reduce water pollution in the harbor. Following completion of the North River and Red Hook WPCPs in 1986 and 1987, respectively, total coliform distributions in 1988 demonstrated significant improvements compared to 1985 before these two plants came on-line. The improvements attributed to CSO controls are also quite apparent: total coliform levels in the harbor declined by more than 50 percent at 45 of 52 stations in 1995 and compliance with water quality standards improved from 87 percent in 1989 to 98 percent in 1995 (Brosnan and Heckler, 1996).

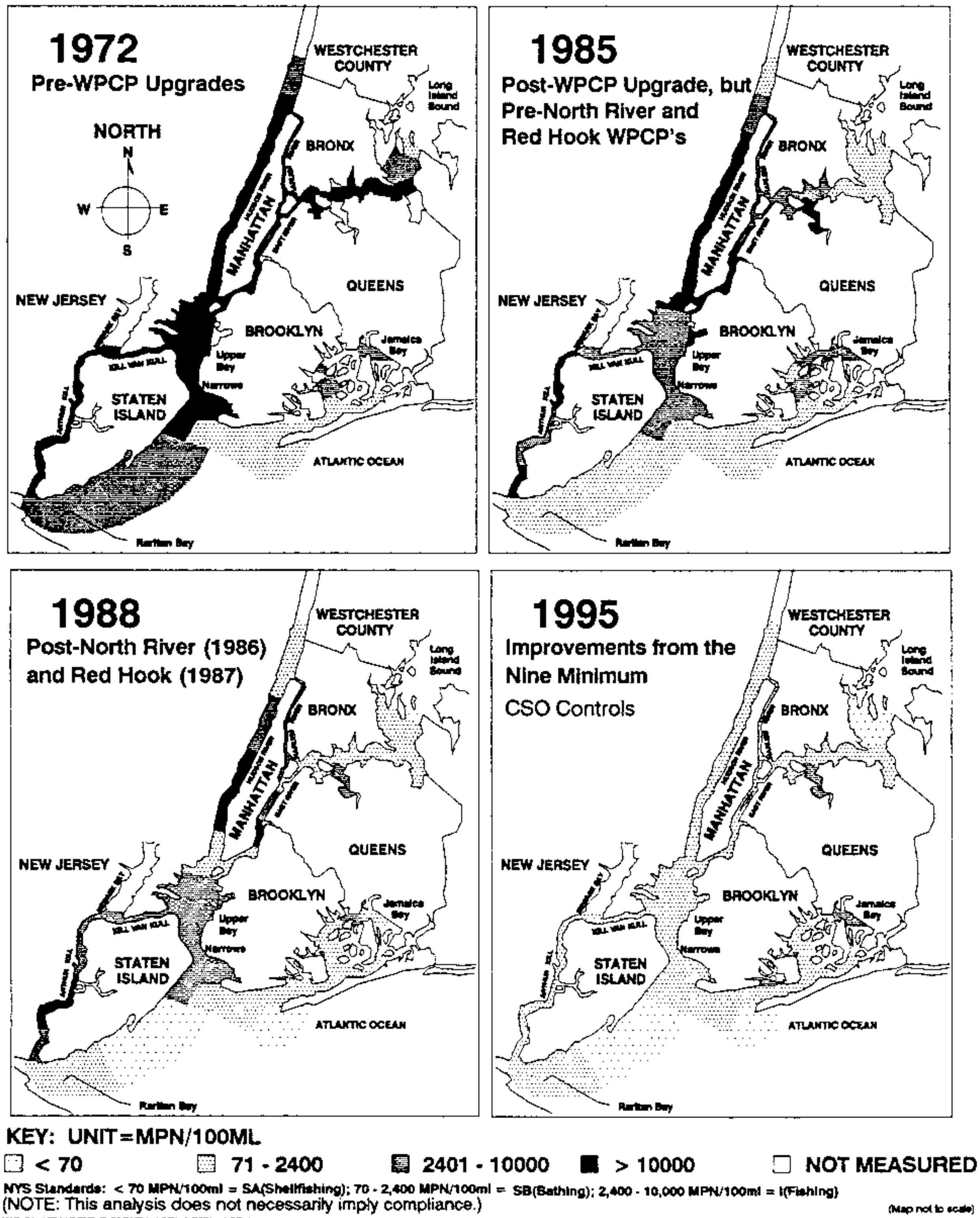
Historically, many public bathing beaches in Lower New York Harbor have been closed to swimming to protect public health because of high bacterial levels that consistently violated water quality standards for primary contact. As a result of the construction and upgrade of water pollution control plants in the harbor, the significant harborwide reductions in coliform bacteria levels (see Figure 6-16) allowed the reopening of public beaches that had been closed for decades. In 1988 Seagate Beach on Coney Island was opened to swimming for the first time in 40 years. South Beach and Midland Beach on Staten Island, closed since the early 1970s, were opened for swimming in 1992. In addition to beach closings because of high bacterial levels, recreational beaches are also closed because of strandings of floatable garbage, including medical waste, on the beaches. As a result of increased abatement and control of discharges of floatable debris, beach closings in New York and New Jersey have been greatly reduced. As of 1996, no beaches in New York City had been closed because of floatables since 1989; New Jersey beaches had not been closed since 1991 (Brosnan and Heckler, 1996).

In addition to closing bathing beaches, the presence of pathogens and pathogenic indicator organisms directly affects shellfish resources. Because pathogen levels were significantly reduced by improved wastewater treatment and year-round chlorination, 67,864 acres of shellfish beds in the estuary have been upgraded since 1985, including removal of seasonal restrictions for 16,000 acres in the New York Bight in 1988, and 13,000 acres in Raritan Bay in 1989 (Gottholm et al., 1993; NJDEP, 1990). Additionally, 1,000 acres of shellfish waters in the Navesink River are being considered for upgrading to a “seasonally approved” classification (HEP, 1996). Shellfishing resources to a greater extent than finfish populations are directly related to improvements in wastewater treatment (Sullivan, 1991).

Although the long-term trends in the abundance of fish such as American shad and striped bass in coastal waters may be the result of degraded water quality, the National Marine Fisheries Service has indicated that overfishing, rather than changes in water quality, is probably the most significant cause of present changes in resource abundance for many species (Sullivan, 1991). The principal commercial fishery of the lower Hudson River estuary is for American shad. Shad landings from 1979 to 1989 were maintained, whereas landings of whiting, red hake, scup, and weakfish decreased during the last decade (Woodhead, 1991). Improved water quality has expanded the spawning area available for American shad (Sullivan, 1991). The prevalence of fin rot in winter flounder declined tenfold in the New York Bight region between 1973 and 1978 for reasons that are not clear (Swanson et al., 1990). Although the causes of fin rot are not well understood, it tends to be more prevalent in shallow inshore

Figure 6-21

Total coliform trends in surface waters of New York Harbor. Summer geometric means for 1972, 1985, 1988, and 1995. *Source: O'Shea and Brosnan, 1997.*



waters receiving municipal effluents, and therefore the decline in the incidence of fin rot lesions might reflect improvements at wastewater treatment plants (Sullivan, 1991).

Populations of some birds in the Hudson Raritan Estuary have historically been influenced by many aspects of this complex urban ecosystem other than water quality. Notable among these factors is the decimation of local bird populations in the latter half of the 19th century by the hunting and milliner's trade (Sullivan, 1991). Before the passage of federal protective legislation, such as the 1913 Migratory Bird Treaty, annual catches for food and feathers totaled more than a million birds per year. Even small songbirds, such as robins, were sought for sale in commercial markets. By 1884 the once abundant populations of common terns, least terns, and piping plovers, formerly present between Coney Island and Fire Island, had been reduced to but a few individuals. Populations of common and roseate terns, herons, snowy egrets, and many other species were similarly affected by hunting.

Populations gradually recovered over the next several decades until development and associated draining and spraying of wetlands for mosquito control encroached on, and degraded, waterfowl habitat. Between the late 1940s and its ban in 1972, DDT was heavily applied to the salt marshes of Long Island and New Jersey; the New Jersey marshes received the heaviest applications for the longest period of time. The DDT was transferred up the food chain to fish and shellfish, which are an important food source for many coastal birds in the harbor. DDT accumulated in bird tissues and contributed to the decline in reproductive success by affecting eggshell thickness. The osprey was probably the species most affected in the Hudson-Raritan Estuary area, although bald eagles and herons were also affected.

Recent concerns for shorebirds include the high concentrations of industrial chemicals such as PCBs measured in mallards, black ducks, scaup, and osprey. Due to the many factors contributing to the abundance of shorebirds and the fact that they can be exposed to more than one geographic area through migration, there is only a tenuous linkage between improved water pollution control efforts and bird populations. Overwintering populations of waterfowl, however, have generally remained stable since the 1980s (Sullivan, 1991). For example, the Canada goose populations of New Jersey increased from about 6,000 in 1975 to 23,200 in 1981 to 124,000 in 1990, a record high for the state. This increase is most likely the result of displacement of geese from other states, particularly Maryland.

Most remarkable among bird population recoveries is the return of herons to the heavily industrialized and highly polluted northwestern portion of Staten Island along the Arthur Kill and Kill Van Kull waterways. In the urban wetlands, undaunted by nearby oil refineries and chemical manufacturing plants, herons and other wading birds are making a comeback. The Harbor Herons Complex, first documented in the industrial Arthur Kill waterway in the 1970s, has become a regionally significant heron and egret nesting rookery (HEP, 1996). In 1974 snowy egrets, cattle egrets, and black-crowned night-herons began nesting on Shooters Island; in 1978 nesting snowy egrets and cattle egrets were found on Prall's Island, a 88-acre high marsh that in the past had served as a disposal site for dredged spoils. By 1981 these birds were joined by glossy ibises, great egrets, and black-crowned night-herons. In 1989 snowy egrets, glossy ibises, cattle egrets, black-crowned night-herons, yellow-crowned night-herons, little blue herons, and great egrets were found on the nearby Isle of Meadows. Ospreys, now nesting in portions of the harbor core area where they had been absent for decades (primarily because of bioaccumulation of DDT), have rapidly become so numerous as to be considered a nuisance by boaters and fishermen. Ten percent of the east coast population of the federally endangered peregrine falcon is located in the Hudson-Raritan Estuary metropolitan area (HEP, 1996).

Fish-eating bird populations have thrived despite the fact that sluggish circulation and urban runoff and municipal and industrial wasteloads characterize these waterways (Hydroqual, Inc., 1991). The Arthur Kill waterway is possibly one of the sites of poorest water quality in New York Harbor. Summer mean DO concentrations in the Arthur Kill, ranging from less than 1 mg/L to about 3 mg/L from 1940 to the mid-1970s, however, steadily improved during the 1970s to concentrations above 5 mg/L by the mid-1980s (Figure 6-22) (Keller et al., 1991; O'Shea and Brosnan, 1997). Average summer concentrations of DO at Shooters Island in the Kill Van Kull further reflect this trend of improvements, increasing from 30 percent in 1974 to near 60 percent saturation in 1995 (O'Shea and Brosnan, 1997). Improvements in DO concentrations, as well as habitat protection efforts by the New York City Audubon Society, may have contributed to the success of populations of herons that feed on pollution-intolerant young fish in the Arthur Kill and its associated tidal creeks and wetlands. A 1988-1989 census of wading bird breeding populations indicated approximately 900-1,200 pairs of breeding herons, egrets, and ibises that constitute possibly the largest colonial waterbird rookery complex in New York State (Trust for Public Lands, 1990).

Summary and Conclusions

In the three centuries since the Governor of New York ordered a sewer system to be constructed in Lower Manhattan, New York City has made considerable progress in protecting public health and improving the water quality of the harbor. Since the early 1900s when the city of New York instituted one of the Nation's first long-term water quality monitoring programs in New York Harbor,

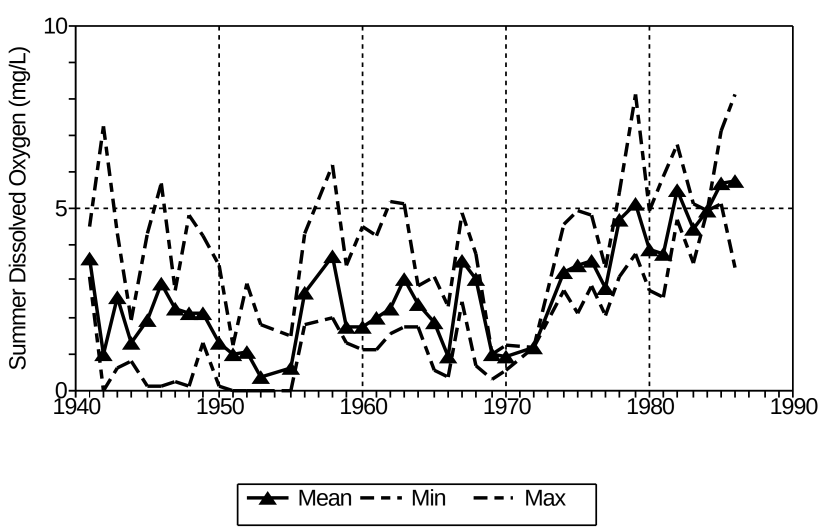


Figure 6-22

Long-term trend in summer (July-September) mean, minimum, and maximum DO in the Arthur Kill (RF1-02030104003).

Source: USEPA (STORET).

the city's efforts to improve the waters of New York have included constructing, maintaining, and upgrading the infrastructure for wastewater collection and treatment, pollution prevention and remediation, water quality monitoring, and programs to protect the natural resources of the estuary and restore disrupted natural drainage patterns to mitigate urban runoff problems.

Although construction and upgrades of municipal wastewater treatment facilities resulted in some water quality improvements beginning in the 1950s, the greatest strides in improving ecological conditions in the harbor can be attributed to new construction and upgrades of municipal wastewater plants in the Hudson-Raritan metropolitan region during the 1970s, largely stimulated by the regulatory requirements of the 1972 CWA. Based on assessments of long-term water quality monitoring data and other environmental indicators, the ecological and water quality conditions of New York Harbor are the best they have been since the early 1900s (NYCDEP, 1999).

Biological indicators of environmental improvement in New York Harbor include the reestablishment of breeding populations of waterfowl (e.g., peregrine falcons, ospreys, herons) in many areas of the estuary, the recovery of Hudson River shortnose sturgeon to record populations, the decline of PCBs in striped bass, and a relaxation of New York State advisories for human consumption of striped bass in parts of the Hudson River. Marine organisms long absent from the waters of the harbor because of poor water quality conditions are now thriving as a result of the cleanup of the harbor. The resurgence of pollution-intolerant benthic organisms in Lower New York Bay and the heavy reinfestation of submerged wooden pilings by marine borers throughout the Hudson-Raritan estuary are strong evidence of the improvement in the ecological condition of the harbor.

Water quality indicators of environmental improvement in the harbor that can be attributed to upgrades of wastewater treatment facilities include significant declines in total and fecal coliform bacteria, dramatic improvements in dissolved oxygen levels, and declines in ammonia-nitrogen and BOD_5 in most areas of the Hudson-Raritan estuary. Controls on releases of heavy metals and toxic chemicals have resulted in a 50-90 percent reduction relative to peak levels of trace metals and chlorinated organic compounds associated with fine-grained sediments in the Hudson River. The 1972 federal ban on lead in gasoline has resulted in declines in lead in the sediments in New York Harbor and many other waterways (O'Shea and Brosnan, 1997).

Resource use indicators of environmental improvements in the harbor include the bacteria-related upgrading of the status of 68,000 acres of shellfish beds, including the lifting of restrictions on harvesting shellfish in 30,000 acres in Raritan Bay and off the Rockaways in the late 1980s. As a result of the dramatic declines in coliform bacterial levels, all New York City beaches, historically closed to swimming since the 1950s, have been open since 1992 and wet-weather swimming advisories have been lifted for all but three beaches (NYCDEP, 1999). These bacteria-related improvements in public and commercial uses of the harbor can be attributed to the continued construction and upgrading of the city's municipal water pollution control plants, the elimination of raw and illegal waste discharges, and the increased efficiency of the combined sewer system (Brosnan and O'Shea, 1996b; Brosnan and Heckler, 1996).

As a result of the clean-up efforts to date in the harbor, the public has enjoyed greatly increased opportunities for recreational uses such as swimming, boating, and fishing. The improvements in water quality also provide substantial benefits to the local economy through commercial fishing and other water-based revenue-generating activities. Although tremendous ecological improvements have resulted from water pollution control efforts implemented since the 1970s, a number of environmental problems remain to be solved for the Hudson-Raritan Estuary. Some contemporary concerns and issues include, for example, contamination of sediments and restrictions on dredge spoil disposal, remaining fish advisories for human consumption, episodic low dissolved oxygen, the occurrence of nuisance algal blooms and effluent controls on nitrogen discharged to the estuary, and increasing nonpoint source runoff from overdevelopment in the drainage basin of the estuary (NYCDEP, 1999). The success of continued water pollution control efforts to remedy these concerns in the Hudson-Raritan Estuary will require financial support from all levels of government, enhanced public awareness about the resource value of the estuary, and strong public stakeholder support for regional coordination of environmental control programs throughout the entire Hudson-Raritan watershed.

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